This material is for the use of members of the MGH DACCPM only

Perioperative Electrophysiology:
Perioperative Management of Pacemakers
Lecture #6
Magnets

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I have no conflict of Interest

1

What do you need to know about Magnets?

- Why you should use a Magnet?
- How will each type of pacer respond to a magnet in a typical situation
- How to use a programmer to understand the programmability associated with many of the pacemakers
- What are the risks associated with a magnet?

2

Why use a Magnet?

- Convert most pacers to asynchronous pacing
- Increase the pacing rate
- Provide estimate of remaining battery life
- Inhibit the rate response mode (RRM)
- Stop a pacemaker-meditated tachycardia
- Collect an EGM (patient activated)
- Determine the likely pacer manufacturer

3

How does a Magnet affect a Pacemaker?

- Magnetic Reed Switch
- Giant Magnetosensitive Resistors
- Hall-Effect Sensor
- Telemetry Coil

4

Reed Switch

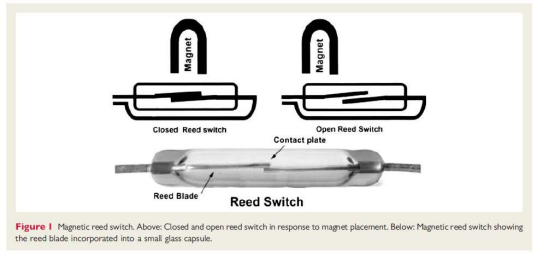
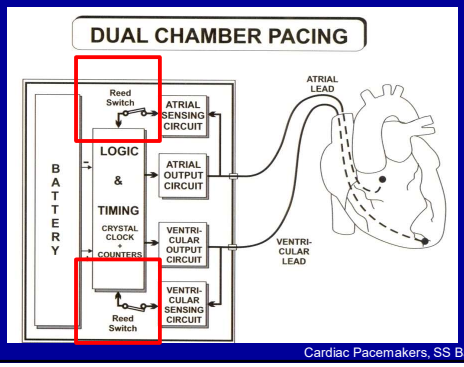


Figure 1 Magnetic reed switch. Above: Closed and open reed switch in response to magnet placement. Below: Magnetic reed switch showing the reed blade incorporated into a small glass capsule.

Clinical Applications of magnets on CRMDs, Jacob S; Europace (2011) 13:1222-30

5

Reed Switch



Cardiac Pacemakers, SS Barold et al

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How does one Apply a Magnet?

9

Useful Tips for Magnet Placement

- Define the border of the pacemaker with a marking pen
- Use a large tegaderm to secure the device
- Check the magnet position often.
- Be careful if patient is in the lateral or prone position
- Use two magnets if the pacemaker is deep in the body (obese patient)

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Define the Borders with a Marking Pen

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Magnet Fixation with a Large Tegaderm

12

Magnet Fixation in Lateral Position

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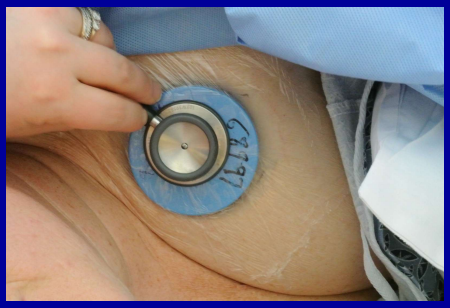
Confirming accurate positioning with a Boston Scientific ICD



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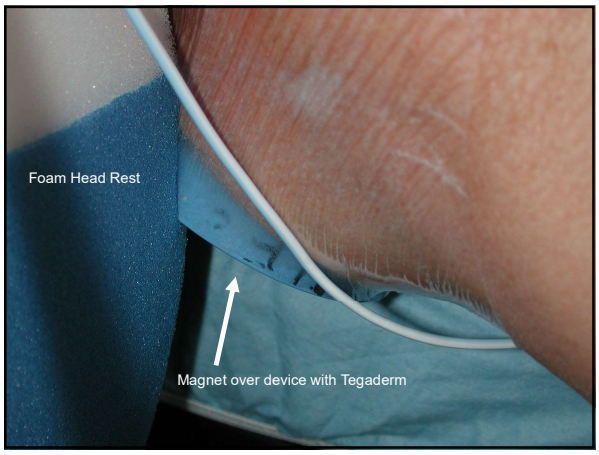

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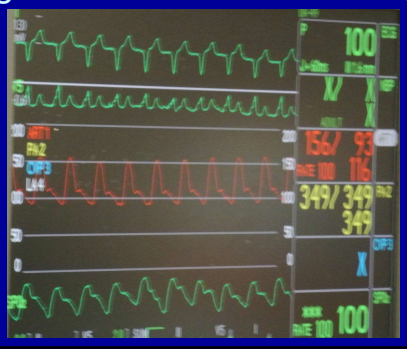
Confirm Some Response to the Magnet to ensure it is working



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What should be expected from pacers of the different Manufacturers?

- Simple answer
- Comprehensive answer

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How will the Pacer Respond to a Magnet? SIMPLE ANSWER

Manufact.	Mode	Tone	RRM	BOL Rate
Medtronic	DOO, VOO, AOO	No	Off	85
Biotronik	DOO, VOO, AOO	No	Off	90
Sorin/ELA	DOO, VOO, AOO	No	Off	96
St Jude	DOO, VOO, AOO	No	Off	98.6/100
Boston Sci	DOO, VOO, AOO	No	Off	100

Assumes the Pacemaker is programmed to respond to a magnet
The magnet is dependent on the baseline programmed mode

Comprehensive Magnet Summary: Heart Rhythm July 2011, p.1114-1154

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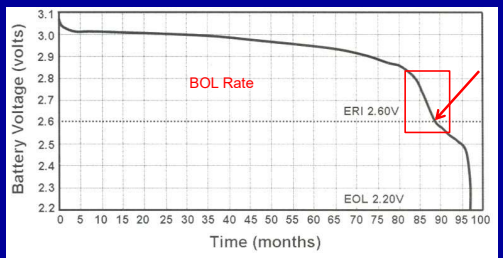
How Does Battery Life Affect a Pacer's Response to a Magnet?



Ellenbogen Clinical Cardiac Pacing 2nd Ed

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How will the Pacer Respond to a Magnet? MORE COMPLEX

Manufact.	Mode	BOL	ERI	Change
Medtronic	DOO, VOO, AOO	85	65	Binary
Biotronik	DOO, VOO, AOO	90	80	Binary
Sorin/ELA	DOO, VOO, AOO	96	80	Gradual
St Jude	DOO, VOO, AOO	98.6/100	86.3/85	Gradual
Boston Sci	DOO, VOO, AOO	100	85	Gradual

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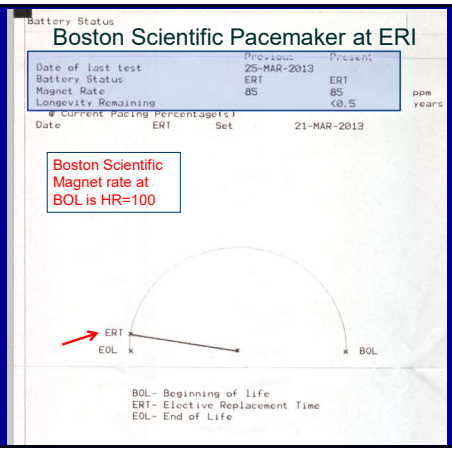
Boston Scientific Pacemaker at ERI



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How will the Pacer Respond to a Magnet? MORE COMPLEX

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St Jude	DOO, VOO, AOO	98.6/100	86.3/85	Gradual
Boston Sci	DOO, VOO, AOO	100	85	Gradual

This does not tell the whole story either…as the magnet decays for some of the manufacturers, the battery decreases toward the ERI Rate

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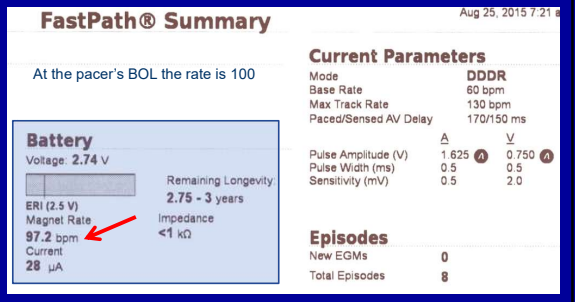
St Jude with 3 Years Remaining



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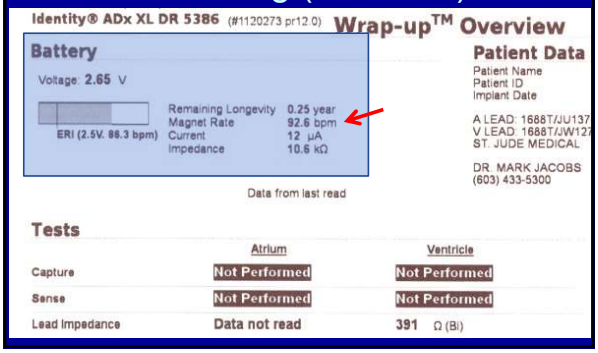
St Jude with 3 months remaining (near ERI)



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How will the Pacer Respond to a Magnet? MORE COMPLEX

Manufact.	Mode	BOL	ERI	Change
Medtronic	DOO, VOO, AOO	85	65	Binary
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Sorin/ELA	DOO, VOO, AOO	96	80	Gradual
St Jude	DOO, VOO, AOO	98.6/100	86.3/85	Gradual
Boston Sci	DOO, VOO, AOO	100	85	Gradual

- No Tone is emitted from a pacemaker upon magnet application
- The Rate Response Mode will be inhibited
- *All of this assumes the pacer is programmed to respond to the magnet*

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The Magnet Response by some Pacemakers is Programmable

- Some pacemakers can be programmed to IGNORE the magnet

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Which Pacer Brands are Programmable ?

- Biotronik
- Boston Scientific
- St Jude

- Medtronic
  - How the pacer responds to a magnet AFTER a programming session is programmable

Only the Sorin/ELA pacemaker is not Programmable in terms of Magnet response

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Appendix 5A Pacemaker magnet response

Manufacturer	Magnet response at beginning of life (BOL)	Magnet response at elective replacement indicator (ERI)*	Is magnet response programmable?†	Audible tones with magnet placement?
BIOTRONIK	1. Pacing mode depends on programming: —ASYNC - Asynchronous pacing (DOO or VOO) @ 90 bpm —SYNC - Programmed pacing mode at programmed rate (not asynchronous) —AUTO - VOO @ 90 bpm for 1st 10 beats then programmed pacing mode at programmed rate 2. Suspends rate response in all modes‡ 3. Pacing amplitudes remain unchanged‡	Pacing mode depends on programming: —ASYNC - VOO @ 80 bpm —SYNC - VOO or VVI @ programmed rate minus 11% —AUTO - VOO @ 80 bpm for 1st 10 beats then VOO or VVI @ programmed rate minus 11%	Yes§	None
Boston Scientific	1. Asynchronous pacing at 100 bpm (DOO or VOO) —Note, pulse width on 3rd pulse reduced by 50% in order to check threshold safety margin 2. Suspends rate response 3. Pacing amplitudes remain unchanged‡	DOO or VOO 85 bpm —Nearer to ERI will pace at 90 bpm —Magnet pacing amplitude between ERI and EOL is 2× last threshold and at least between 3.5 and 5 V	Yes —If magnet response programmed to "IGM", device will not result in asynchronous pacing when magnet is placed over the pacemaker —To activate magnet response, the feature must be programmed back to "ON"	None
ELA/Sorin	1. Asynchronous pacing at 96 bpm (DOO with max AV delay or VOO) 2. Suspends rate response 3. Pacing amplitudes go to 5 V and 0.5 ms unless programmed higher‡ —Note, 8 asynchronous beats after magnet removal; first 6 at magnet ratio at programmed output with AV Delay at 95 ms and last 2 beats at base rate, programmed output, and Max AV Delay	Gradual decrease to DOO or VOO @ 80 bpm	No	None
Medtronic	1. Asynchronous pacing at 85 bpm (DOO or VOO) 2. Suspends rate response 3. Pacing amplitudes remain unchanged‡ —Note, first 3 beats with magnet application are at 100 bpm with reduction of pulse width on 3rd pulse reduced by 25% in order to check threshold safety margin	VOO @ 65 bpm‖	No	None
St. Jude Medical	1. Asynchronous pacing at 100 bpm or 98.6 bpm (VOO or DOO) depending on the model** —Magnet rate will gradually decline throughout the life of the device. 2. Suspends rate response 3. Pacing amplitudes vary by model‡	VOO at <85 bpm or 86.3 bpm, depending on the model‖ —Magnet pacing amplitude between ERI and EOL is 2× last threshold when AutoCapture enabled	Yes —If magnet response is programmed to "OFF" device will not result in magnet pacing rate —If magnet response is programmed to "Event Snapshots + Battery Test" device will trigger an event snapshot and then pace at the magnet rate —To activate magnet response, the feature must be programmed back to "Battery Test" (Do) —VARIO enabled devices will initiate a magnet rate followed by a threshold test**	None

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How do we Learn about this Complexity?

- We will go through each manufacturer in detail
- I will show you how to use the programmer to determine and/or change the programmed magnet response

This is where we will begin part 2 of the Magnet Lecture

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Perioperative Electrophysiology:

Perioperative Management of Pacemakers
Lecture #6
Magnets Part 2

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I have no conflict of Interest

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How will the Pacer Respond to a Magnet?

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Sorin/ELA	DOO, VOO, AOO	96	80	Gradual
St Jude	DOO, VOO, AOO	98.6/100	86.3/85	Gradual
Boston Sci	DOO, VOO, AOO	100	85	Gradual

- The Rate Response Mode will be inhibited
- No Tone is emitted from a pacemaker upon magnet application
- *All of this assumes the pacer is programmed to respond to the magnet*

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Pacemaker Brands that are Programmable

- Biotronik
- Boston Scientific
- St Jude
- Medtronic*

Only the Sorin/ELA pacemaker is not Programmable in terms of Magnet response

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Why are we worried about Magnet-Response Programmability?

- The Pacemaker can be programmed to ignore the magnet
- The Pacemaker can be programmed to respond in an manner other than the typical asynchronous pacing

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Appendix 5A Pacemaker magnet response

Manufacturer	Magnet response at beginning of life (BOL)	Magnet response at elective replacement indicator (ERI)*	Is magnet response programmable?†	Audible tones with magnet placement?
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Boston Scientific	1. Asynchronous pacing at 100 bpm (DOO or VOO) —Note, pulse width on 3rd pulse reduced by 50% in order to check threshold safety margin 2. Suspends rate response 3. Pacing amplitudes remain unchanged‡	DOO or VOO 85 bpm —Nearer to ERI will pace at 90 bpm —Magnet pacing amplitude between ERI and EOL is 2× last threshold and at least between 3.5 and 5 V	Yes —If magnet response programmed to "YGM", device will not result in asynchronous pacing when magnet is placed over the pacemaker —To activate magnet response, the feature must be programmed back to "ON"	None
ELA/Sorin	1. Asynchronous pacing at 96 bpm (DOO with max AV delay or VOO) 2. Suspends rate response 3. Pacing amplitudes go to 5 V and 0.5 ms unless programmed higher‡ —Note, 8 asynchronous beats after magnet removal; first 6 at magnet rate at programmed output with AV Delay at 95 ms and last 2 beats at base rate, programmed output, and Max AV Delay	Gradual decrease to DOO or VOO @ 80 bpm	No	None
Medtronic	1. Asynchronous pacing at 85 bpm (DOO or VOO) 2. Suspends rate response 3. Pacing amplitudes remain unchanged‡ —Note, first 3 beats with magnet application are at 100 bpm with reduction of pulse width on 3rd pulse reduced by 25% in order to check threshold safety margin	VOO @ 65 bpm‖	No	None
St. Jude Medical	1. Asynchronous pacing at 100 bpm or 98.6 bpm (VOO or DOO) depending on the model** —Magnet rate will gradually decline throughout the life of the device. 2. Suspends rate response 3. Pacing amplitudes vary by model‡	VOO at <85 bpm or 84.3 bpm, depending on the model‖ —Magnet pacing amplitude between ERI and EOL is 2× last threshold when AutoCapture enabled	Yes —If magnet response is programmed to "OFF" device will not result in magnet pacing rate —If magnet response is programmed to "Event Snapshots + Battery Test" device will trigger an event snapshot and then pace at the magnet rate —To activate magnet response, the feature must be programmed back to "Battery Test" (Do) —VARIO enabled devices will initiate a magnet rate followed by a threshold test**	None

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What will we do in this Lecture?

- We will review the HRS document for each of the 5 Manufacturers
- We will focus on the magnet-response programmability
- Conclude with a Super Summary of the Magnet Response

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Biotronik

Appendix 5A Pacemaker magnet response

Manufacturer	Magnet response at beginning of life (BOL)	Magnet response at elective replacement indicator (ERI)*
BIOTRONIK	1. Pacing mode depends on programming: —ASYNC - Asynchronous pacing (DOO or VOO) @ 90 bpm —SYNC - Programmed pacing mode at programmed rate (not asynchronous) —AUTO - VOO @ 90 bpm for 1st 10 beats then programmed pacing mode at programmed rate 2. Suspends rate response in all modes§ 3. Pacing amplitudes remain unchanged‡	Pacing mode depends on programming: —ASYNC - VOO @ 80 bpm —SYNC - VDD or VVI @ programmed rate minus 11% —AUTO - VOO @ 80 bpm for 1st 10 beats then VDD or VVI @ programmed rate minus 11%

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Biotronik Programmability

- Three Magnet Modes:
  - ASYNC: Async pacing at 90 (DOO/VOO/AOO)
  - SYNC: Programmed mode and rate (OFF)
  - AUTO: VOO at 90 for 10 beats, then programmed mode & rate (almost OFF)

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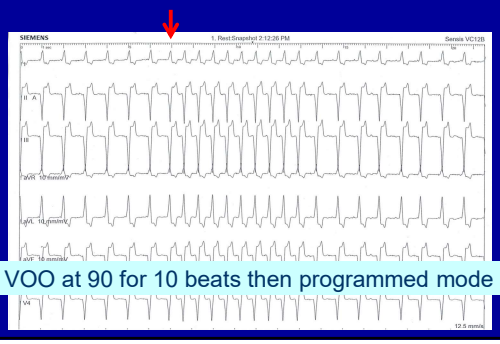
Biotronik Pacer with Magnet: Which Mode is this?



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Biotronik Programmability

- Three Magnet Modes:
  - ASYNC: Async pacing at 90 (DOO/VOO/AOO)
  - SYNC: Programmed mode and rate (IGNORES)
  - AUTO: VOO at 90 for 10 beats, then programmed mode and rate (IGNORES)

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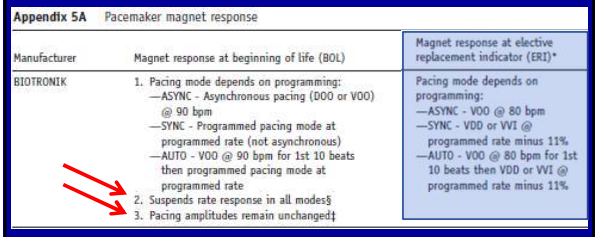
Biotronik



Appendix 5A Pacemaker magnet response

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At ERI, the pacing modes change to VVI or VDD to preserve battery life
Thus the ASYNC magnet mode is VOO

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Biotronik ERI Case:

- 80 yo F with severe AS for TAVR
- PMHx
  - CAD s/p CABG x 1
  - MVR and TV ring
  - Post op Pacer for SSS

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EKG

- AV Paced 80

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Preop Assessment

- No Pacemaker assessment in the chart or electronic medical record
- Patient thinks pacer is Medtronic

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Medtronic Programmer Application

- Not detecting???

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Magnet Application

- HR paced at 90, but only briefly
- Not Medtronic—probably Biotronik

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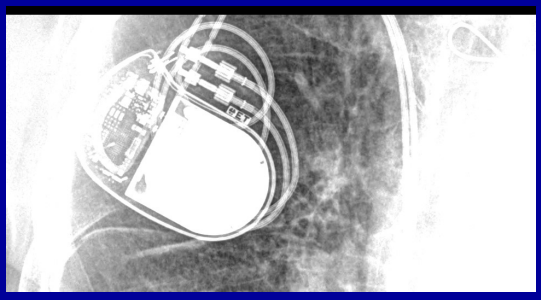
What is the Manufacturer?



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Biotronik Interrogation

Parameters		
Battery status		OK
Calculated ERI		0 Y. 0 Mo.
Magnet effect		AUTO
	Previous	Current
Mode		DDDR
Basic/Night rate...		80/80 bpm
Rate hysteresis...		OFF bpm
Repetitive		-----
Scan		-----
Night program		OFF bpm
Night begins		-----
Night ends		-----

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Intraoperative Course

- Cardiologist and EP doctor informed
- Discussed the pacer function change if the device were to go into ERI mode
  - At ERI, the pacing mode would change from DDDR to VDD
  - VDD mode could take away the synchronized atrial kick unless the intrinsic rate exceeded 80

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Clinical Course

- V-wire placed (standard for TAVR)
- Then noticed patient V-pacing at 71 (no longer A-V at 80) and BP decreased significantly (120→98 systolic)

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What was Happening?

- ERI reached:
  - Pacer rate decreased by 11% (80-71)
  - Pacer Mode changed to VDD (lost atrial kick)
  - Magnet response decreased 11% also: 90 to 80 bpm
  - Magnet applied→ ERI confirmed as magnet rate 80 now

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Clinical Course

- Temp atrial pacing wire placed
- Pacemaker revision the next day

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Take Home Message

- When a battery reaches ERI/EOL the pacing mode and rate can change
- If a patient is near ERI/EOL in an elective setting, one should consider consulting an EP physician prior to proceeding with the case
- If you proceed, know what the ERI-related pacemaker changes will be.

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Biotronik Magnet Response Programmability

- Magnet Control area in cryptic location
- Three options for the magnet response:
  - ASYNC
  - AUTO
  - SYNC
- Very useful information on programmer

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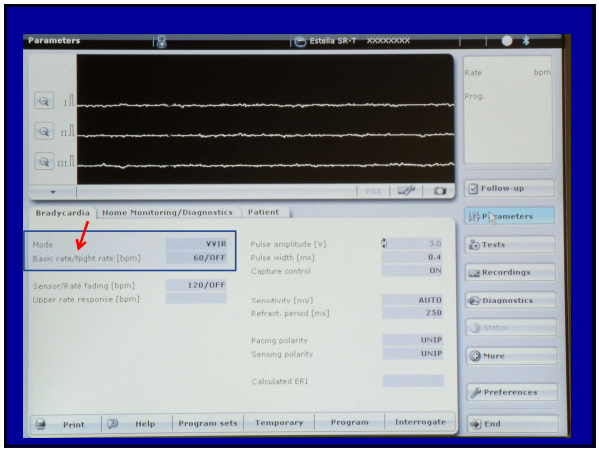

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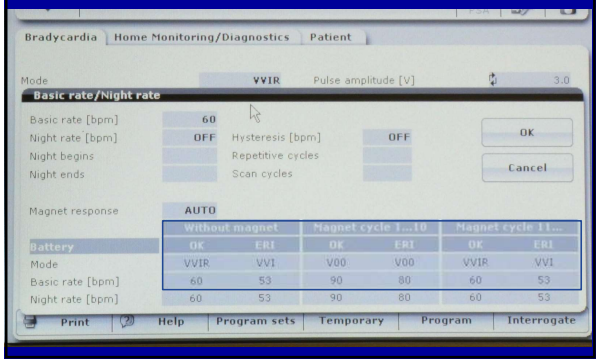
Biotronik AUTO Magnet Mode



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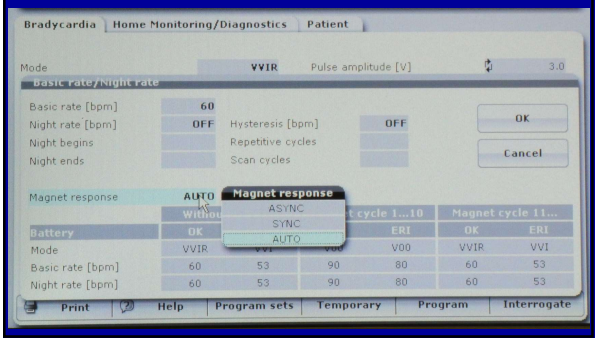
Changing Magnet Response Mode



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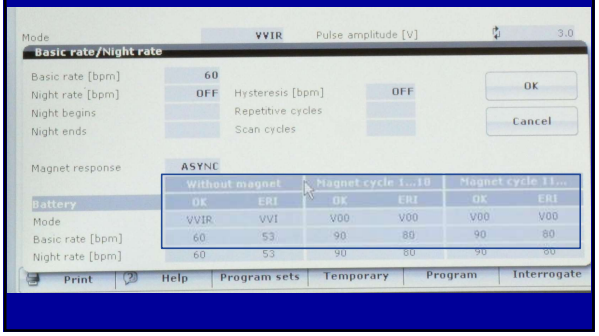
Biotronik ASYNC Magnet Mode



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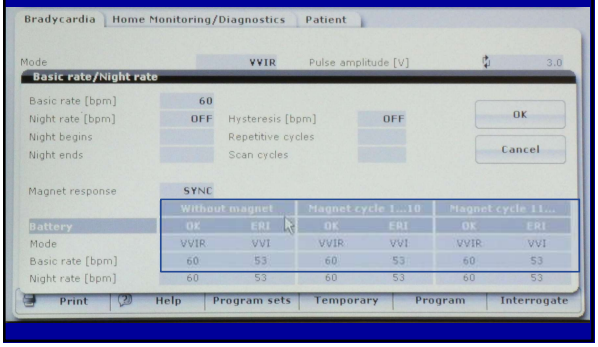
Biotronik SYNC Magnet Mode



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Biotronik Summary

Appendix 5A Pacemaker magnet response

Manufacturer	Magnet response at beginning of life (BOL)	Magnet response at elective replacement indicator (ERI)*
BIOTRONIK	1. Pacing mode depends on programming: —ASYNC - Asynchronous pacing (D00 or V00) @ 90 bpm —SYNC - Programmed pacing mode at programmed rate (not asynchronous) —AUTO - V00 @ 90 bpm for 1st 10 beats then programmed pacing mode at programmed rate 2. Suspends rate response in all modes§ 3. Pacing amplitudes remain unchanged‡	Pacing mode depends on programming: —ASYNC - V00 @ 80 bpm —SYNC - VD0 or VVI @ programmed rate minus 11% —AUTO - V00 @ 80 bpm for 1st 10 beats then VD0 or VVI @ programmed rate minus 11%

The Magnet Rate is binary—either 90 or 80 with no intermediary rates during Battery decay.

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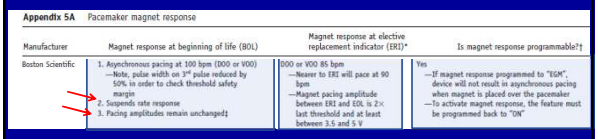
Boston Scientific



Appendix 5A Pacemaker magnet response

Manufacturer	Magnet response at beginning of life (BOL)	Magnet response at elective replacement indicator (ERI)*	Is magnet response programmable?†
Boston Scientific	1. Asynchronous pacing at 100 bpm (D00 or V00) —Note, pulse width on 3rd pulse reduced by 50% in order to check threshold safety margin 2. Suspends rate response 3. Pacing amplitudes remain unchanged‡	D00 or V00 85 bpm —Nearer to ERI will pace at 90 bpm —Magnet pacing amplitude between ERI and EOL is 2x last threshold and at least between 3.5 and 5 V	Yes —If magnet response programmed to "EGM", device will not result in asynchronous pacing when magnet is placed over the pacemaker —To activate magnet response, the feature must be programmed back to "ON"

Magnet mode will be AOO if base mode is AAI
Magnet mode decreases gradually to ERI rate of 85

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Boston Scientific Magnet-Response Programmability

- Three Magnet Response Options:
  1. ASYNC / Pace Async
  2. EGM / Store EGM ("OFF")
  3. OFF

Biotronik Responses
1. ASYNC
2. AUTO (Almost "OFF")
3. SYNC ("OFF")

Unlike the St Jude Pacers which can store an EGM and Async pace thereafter, Boston Scientific Pacers can do either one operation or the other, but not both

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Boston Scientific Programmer

- Programmer interface varies significantly depending on the device's age
- We will review three interfaces

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Altrua Pacemaker

- Old Boston Scientific Pacemaker

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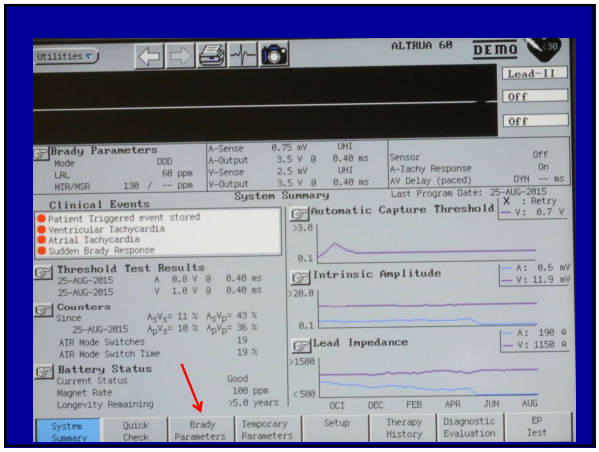

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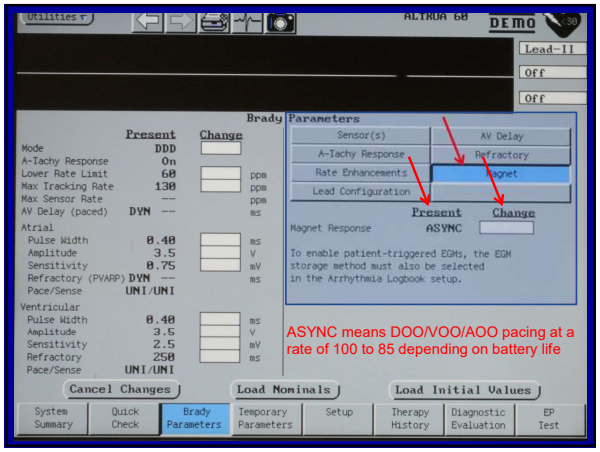

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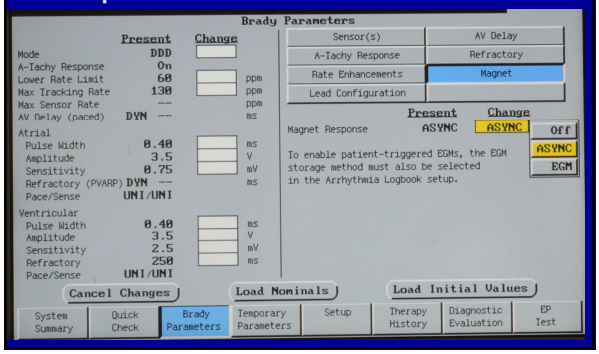
Three Magnet Response Options for Boston Scientific



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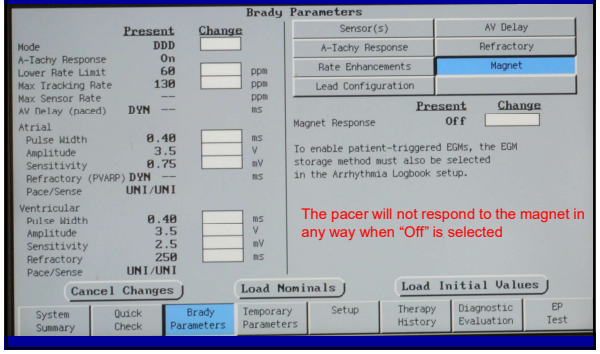
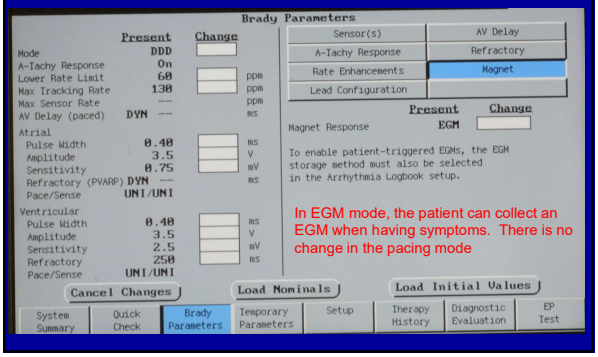
OFF Mode



72

EGM Option



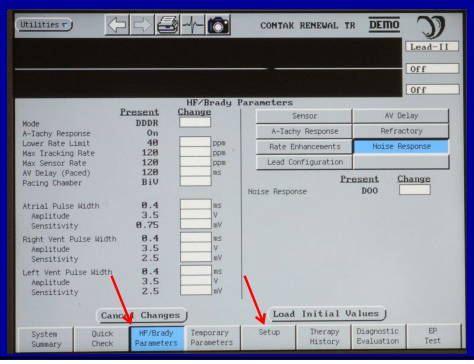
73

Contak Renewal

- Slightly newer Boston Scientific device

74

Contak Renewal



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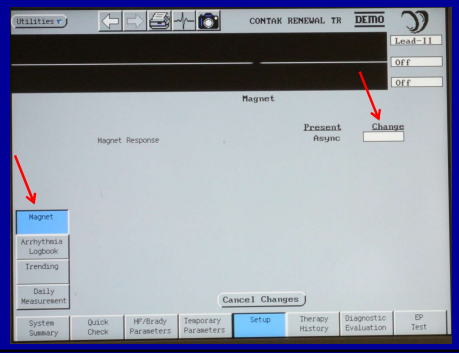

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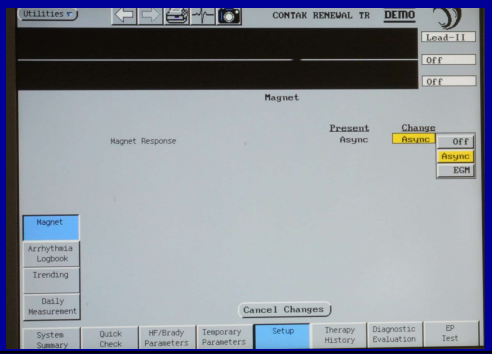
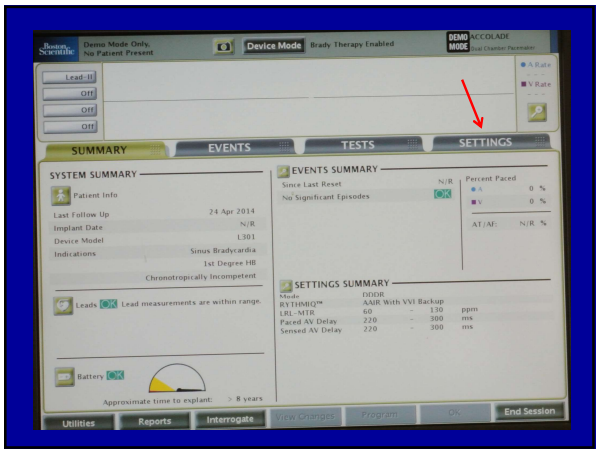


77

Newer Device--Accolade

- Completely different platform
- Much easier to use

78



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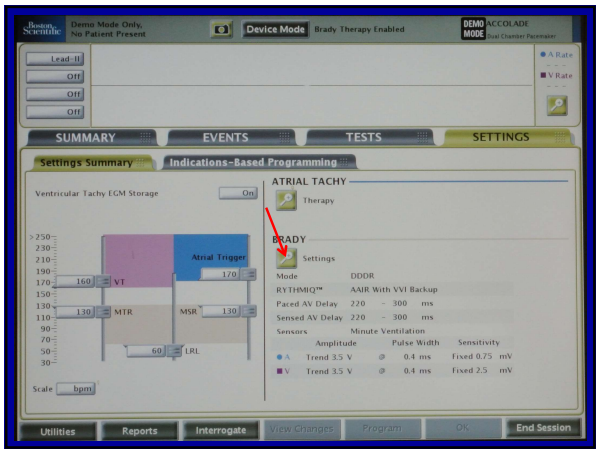

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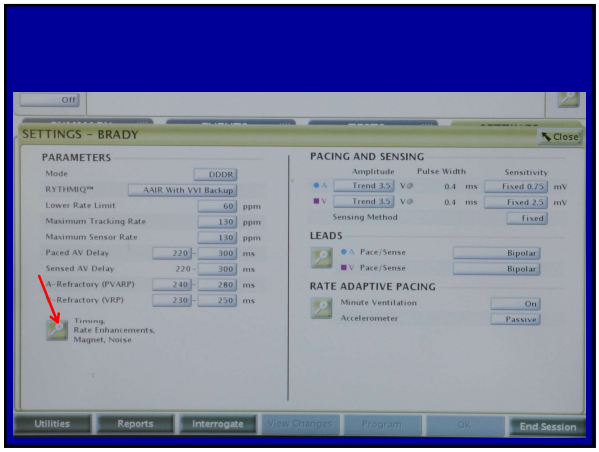

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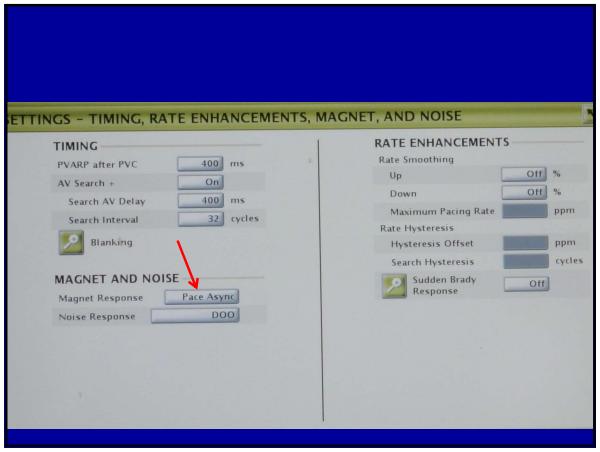

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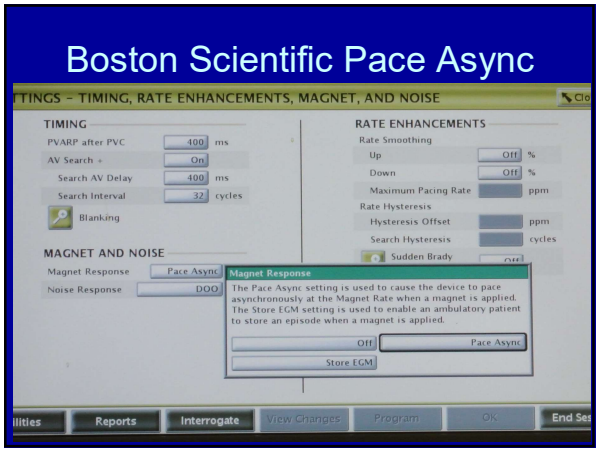

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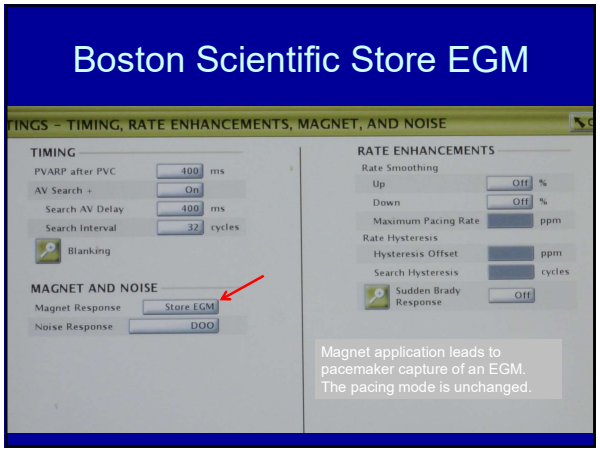

84

Boston Scientific Summary

- BOL 100 ERI 85 with gradual decrease
  - DOO, VOO, or AOO depending on base mode
- Three modes of response to magnet
  - Pace Async
  - Store EGM (only stores EGM—no pacing)
  - Off

85

ELA/Sorin

- Very rare to see this device at MGH

87

ELA/Sorin

Appendix 5A Pacemaker magnet response

Manufacturer	Magnet response at beginning of life (BOL)	Magnet response at elective replacement indicator (ERI)*	Is magnet response programmable?†
ELA/Sorin	1. Asynchronous pacing at 96 bpm (DOO with max AV delay or VOO) 2. Suspends rate response 3. Pacing amplitudes go to 5 V and 0.5 ms unless programmed higher‡	Gradual decrease to DOO or VOO @ 80 bpm	No

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88

ELA/Sorin Summary

- Pacing Rates are 96 with gradual decrease to 80 at ERI
- Pacing Amplitude is increased to 5 Volts
- There is magnet-related pacing for 8 beats after Magnet removal
- Not Programmable

89

Medtronic

- Very common pacemaker in clinical practice

90

Medtronic Pacer Magnet Response

Appendix 5A Pacemaker magnet response

Manufacturer	Magnet response at beginning of life (BOL)	Magnet response at elective replacement indicator (ERI)*
Medtronic	1. Asynchronous pacing at 85 bpm (DOO or VOO) 2. Suspends rate response 3. Pacing amplitudes remain unchanged‡ —Note, first 3 beats with magnet application are at 100 bpm with reduction of pulse width on 3rd pulse reduced by 25% in order to check threshold safety margin	VOO @ 65 bpm#

If the pacer is set as AAI or AAIR, magnet application will convert the device to a AOO mode
If the patient is set in the MVP Mode (AAIR < -- > DDDR), magnet application will convert the device to DOO

91

Threshold Margin Test

Appendix 5A Pacemaker magnet response

Manufacturer	Magnet response at beginning of life (BOL)	Magnet response at elective replacement indicator (ERI)*
Medtronic	1. Asynchronous pacing at 85 bpm (DOO or VOO) 2. Suspends rate response 3. Pacing amplitudes remain unchanged‡ —Note, first 3 beats with magnet application are at 100 bpm with reduction of pulse width on 3rd pulse reduced by 25% in order to check threshold safety margin	VOO @ 65 bpm#

1. Threshold Margin Test done on many of the Medtronic pacers immediately upon magnet application—3 beats at 100 bpm
2. Older devices have a reduction in pulse width as above
3. Newer devices have a reduction in amplitude on 3rd beat
4. ICD platform devices (EnRhythm, Revo, Consulta, Advisa, and Syncra) do not include a TMT

TAKE HOME MESSAGE: Do not assess the Magnet Rate until after 5 beats

92

ERI Response

Appendix 5A Pacemaker magnet response

Manufacturer	Magnet response at beginning of life (BOL)	Magnet response at elective replacement indicator (ERI)*
Medtronic	1. Asynchronous pacing at 85 bpm (DOO or VOO) 2. Suspends rate response 3. Pacing amplitudes remain unchanged‡ —Note, first 3 beats with magnet application are at 100 bpm with reduction of pulse width on 3rd pulse reduced by 25% in order to check threshold safety margin	VOO @ 65 bpm#

The pacer will typically convert to a VVI mode when ERI occurs to conserve battery life. Thus the magnet response is VOO when the device has reached ERI.

93

Magnet Response Programmability

Appendix 5A Pacemaker magnet response

Manufacturer	Magnet response at beginning of life (BOL)	Magnet response at elective replacement indicator (ERI)*	Is magnet response programmable?†
Medtronic	1. Asynchronous pacing at 85 bpm (DOO or VOO) 2. Suspends rate response 3. Pacing amplitudes remain unchanged‡ —Note, first 3 beats with magnet application are at 100 bpm with reduction of pulse width on 3rd pulse reduced by 25% in order to check threshold safety margin	VOO @ 65 bpm#	No

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Pseudo-Magnet Dysfunction

- 82 yo F having cranial tumor resection
- Has a VVI Medtronic Pacemaker
- In the recent pacer report, the staff notices that under “Sensor” the report says ON
- The staff requests a preop interrogation to turn off the Rate Response Mode (if it in fact is on)

95

Clinical Course

- The interrogation reveals that the mode is in fact VVI—there is no active RRM
- The LRL is 50
- The patient has an underlying rhythm (A Fib) with variable ventricular response
  - 40% V-paced
  - 60% V-sensed

96

Clinical Course

- The pacer is kept in VVI mode
- The staff will use a magnet as necessary intraop if bradycardia occurs

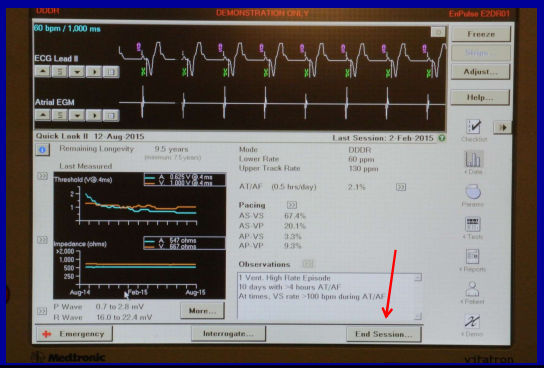
97

Clinical Course

- The programming session is ended in normal fashion

98

End Session Window



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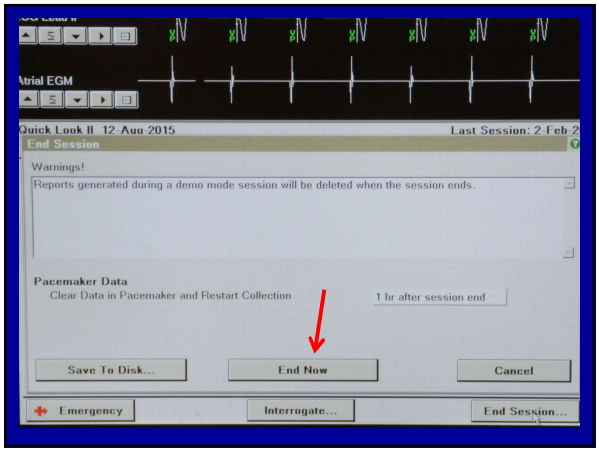

100

Clinical Course

- The patient is positioned and prepped.
- The staff wanted to ensure that she could use the magnet mode if necessary
- She placed a magnet over the device expecting the pacer to convert to VOO at 85

101

Clinical Course

- The magnet did not affect the pacemaker—she was certain the magnet was on the pacer

102

Clinical Course

- She called an anesthesia tech and asked for another magnet
- She placed the new magnet on the patient and it worked—VOO at 85

103

Clinical Course

- I recommended that she now try to use the first (and presumed defective magnet).
- The original magnet now worked as well
- What happened?

104

Medtronic

CRDM Technical Services
Standard Letter

MAGNET USE WITH MEDTRONIC PACEMAKERS

The guidance provided in this letter is for healthcare providers and Medtronic representatives, and it applies to the following Medtronic device types:

- IPG-Implantable Pulse Generators (Pacemakers)
- CRT-P-Cardiac Resynchronization Therapy Pacemakers

Overview

For Medtronic IPGs or CRT-Ps with magnet mode functionality, when the Medtronic magnet (Model 174105 or Model 9466) is placed directly over the device, the device's pacing mode and pacing rate are affected. (Note: The model AT501 does not respond to a magnet with asynchronous pacing). Once the magnet is removed the device returns to normal function immediately with no permanent changes.
Note: Device labeling must be reviewed for specific information on how a device will respond when the Medtronic magnet is applied.

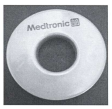

Figure 1: Model 174105 and Model 9466 Magnet Description: Blue-coated, ring-shaped permanent ferrous magnet with minimum field strength of 90 Gauss when measured 1.5 inches from either flat side of the magnet. See next page for magnet storage and handling instructions.

When in magnet mode, the device switches to an asynchronous mode and the resulting pacing rate provides an indication of the status of the device. In general, when in magnet mode, Medtronic pacemakers pace at either 85 bpm when the device is operating at normal conditions or 65 bpm when the device has reached its recommended replacement time (RRT) or the device has experienced an electrical reset. In all cases, refer to the product manual (available at www.manuals.Medtronic.com) to determine the pacemaker's magnet pacing rates, as the magnet pacing rates of older Medtronic pacemakers may be different than 85 bpm and 65 bpm.

For certain Medtronic pacemaker models (including Kappa, EnPulse, Adapta, Versa or Sensia), the magnet response will be suspended for 1 hour following an interrogation, unless the "End Now" command is chosen when ending the programmer session.

105

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106

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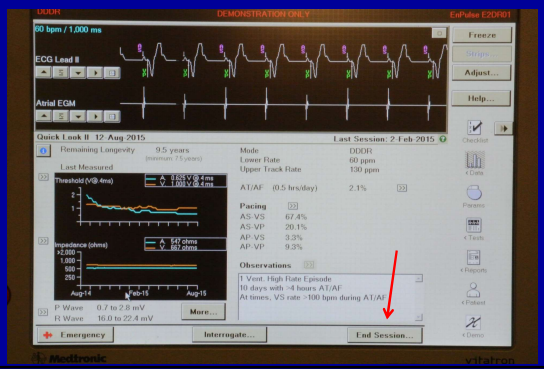
What is the "End Now" command?

107

End Session Window



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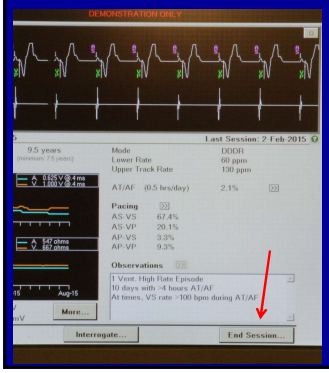
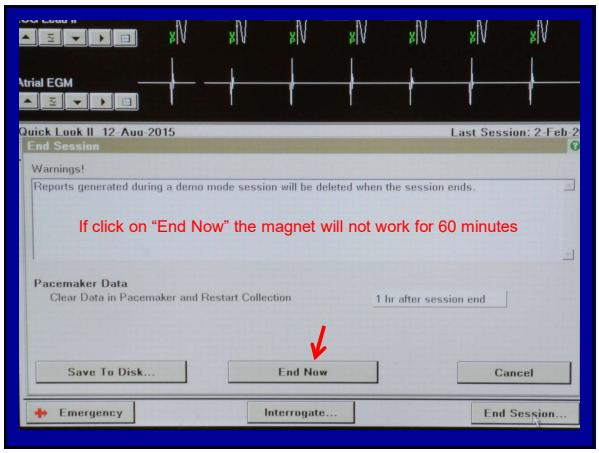
End Session Window



When the programmer clicks on the End Session Box, two responses are possible:

1. Another Screen Appears: Depending how you proceed, the pacer may or may not be responsive to a magnet for the next 60 minutes
2. Session Ends: Pacer immediately responsive to the magnet

109



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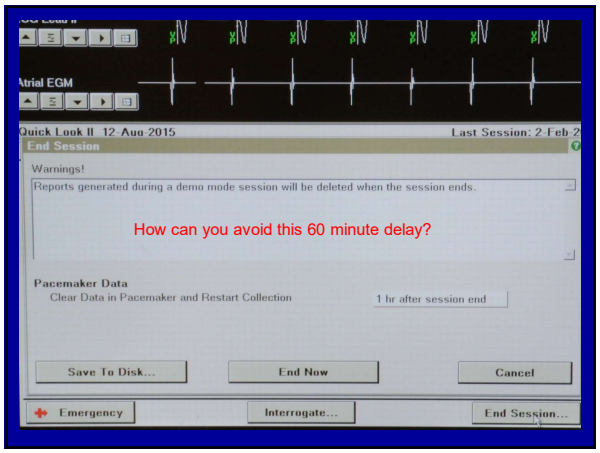

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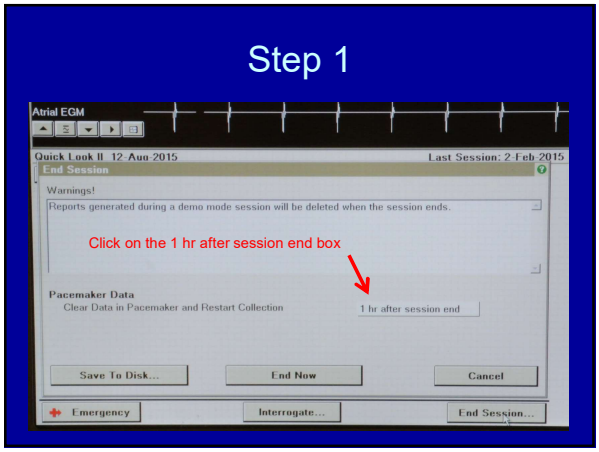

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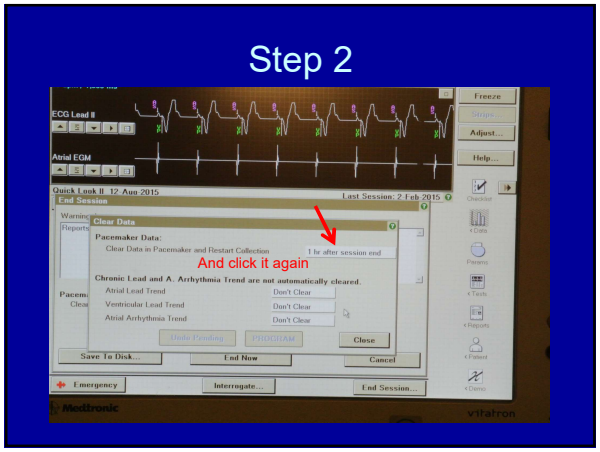

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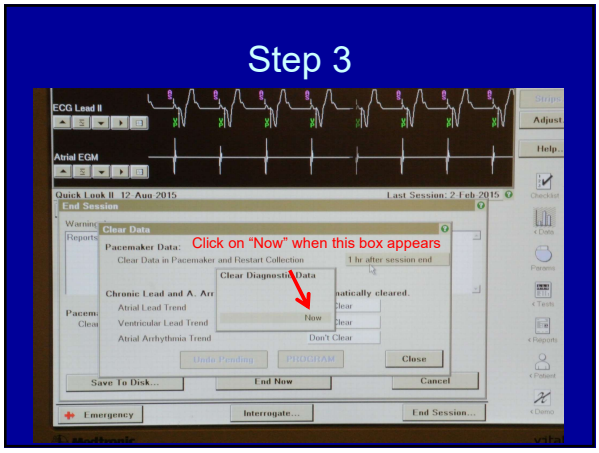

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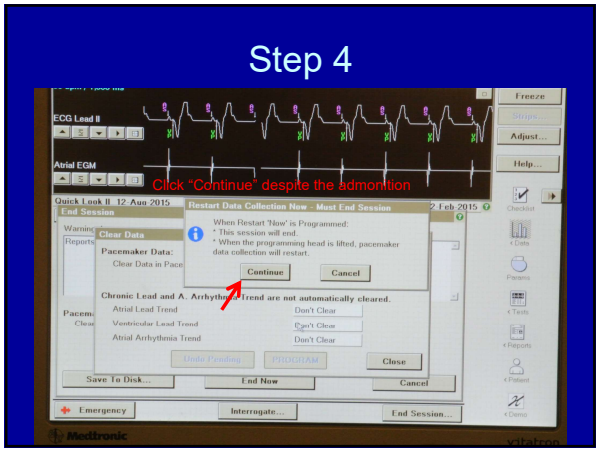

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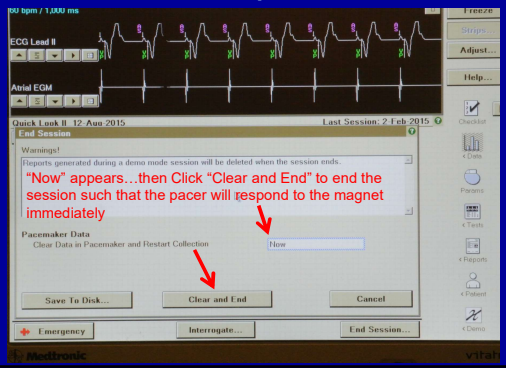
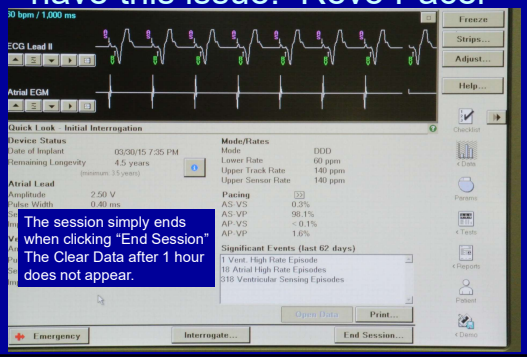
Step 5



116

Newer Medtronic Pacers do not have this issue: Revo Pacer



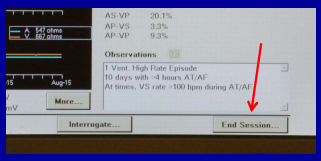
117

How will you know if the Pacer could be affected by this issue?

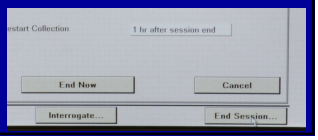
- Simple Answer: It depends on the programmer response when you click "End Session"

118

End Session Window



Session Ends: Magnet-Responsive immediately



119

Which Medtronic Pacemakers may be unresponsive to a magnet for 60 minutes after a programming session?

YES	NO
Kappa	En Rhythm (ATP)
EnPulse	Revo (MRI)
Adapta	Advisa (MRI)
Versa	Viva (CRT-P)
Sensia	Consulta (CRT-P)
	Syncra (CRT-P)

Pacers from the left column will not respond to a magnet for 60 minutes after Interrogation unless a special "end-session" method is used

120

Medtronic Pacer Magnet Response Summary

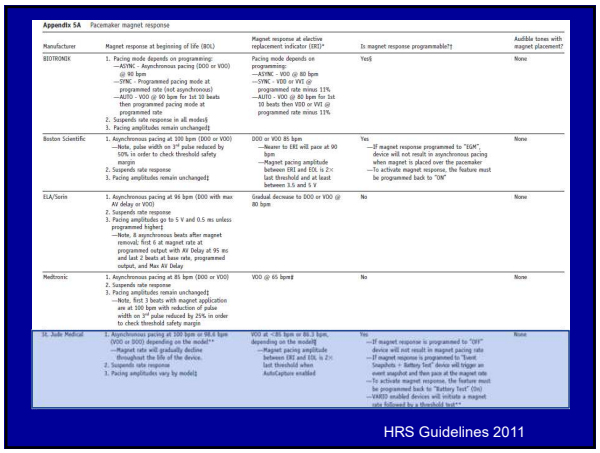
- BOL—85 bpm DOO, VOO or AOO
- ERI—65 bpm VOO or AOO
- Some pacers are "programmable"
  - Some pacers will be unresponsive to a magnet 60 minutes after a programmer session with the standard end-session process

121

St Jude Medical Pacemakers

- Very common in clinical practice
- Programmable

122



Appendix 5A Pacemaker magnet response

Manufacturer	Magnet response at beginning of life (BOL)	Magnet response at elective replacement indicator (ERI)*	Is magnet response programmable?†	Audible tones with magnet placement?
BIOTRONIK	1. Pacing mode depends on programming: —ASYNC - Asynchronous pacing (DOO or VOO) @ 80 bpm —SYNC - Programmed pacing mode at programmed rate (not asynchronous) —AUTO - VOO @ 80 bpm for 1st 10 beats then programmed pacing mode at programmed rate 2. Suspends rate response in all modes‖ 3. Pacing amplitudes remain unchanged‖	Pacing mode depends on programming: —ASYNC - VOO @ 80 bpm —SYNC - VOO or VVI @ programmed rate minus 11% —AUTO - VOO @ 80 bpm for 1st 10 beats then VOO or VVI @ programmed rate minus 11%	Yes‖	None
Boston Scientific	1. Asynchronous pacing at 100 bpm (DOO or VOO) —Note, pulse width on 1st pulse reduced by 50% in order to check threshold safety margin 2. Suspends rate response 3. Pacing amplitudes remain unchanged‡	DOO or VOO 85 bpm —Nearer to ERI will pace at 90 bpm —Magnet pacing amplitude between ERI and EOL is 2× last threshold and at least between 3.5 and 5 V	Yes —If magnet response programmed to "EGM", device will not result in asynchronous pacing when magnet is placed over the pacemaker —To activate magnet response, the feature must be programmed back to "ON"	None
ELA/Sorin	1. Asynchronous pacing at 96 bpm (DOO with max AV delay or VOO) 2. Suspends rate response 3. Pacing amplitudes go to 5 V and 0.5 ms unless programmed higher‡ —Note, 8 asynchronous beats after magnet removal; first 6 at magnet rate at programmed output with AV Delay at 95 ms and last 2 beats at base rate, programmed output, and Max AV Delay	Gradual decrease to DOO or VOO @ 80 bpm	No	None
Medtronic	1. Asynchronous pacing at 85 bpm (DOO or VOO) 2. Suspends rate response 3. Pacing amplitudes remain unchanged‡ —Note, first 3 beats with magnet application are at 100 bpm with reduction of pulse width on 3rd pulse reduced by 25% in order to check threshold safety margin	VOO @ 65 bpm‖	No	None
St. Jude Medical	1. Asynchronous pacing at 100 bpm or 98.6 bpm (VOO or DOO) depending on the model‡‡ —Magnet rate will gradually decline throughout the life of the device. 2. Suspends rate response 3. Pacing amplitudes vary by model‡	VOO at <85 bpm or 86.3 bpm, depending on the model‖ —Magnet pacing amplitude between ERI and EOL is 2× last threshold when AutoCapture enabled	Yes —If magnet response is programmed to "OFF" device will not result in magnet pacing rate —If magnet response is programmed to "Event Snapshots + Battery Test" device will trigger an event snapshot and then pace at the magnet rate —To activate magnet response, the feature must be programmed back to "Battery Test" (On) —VARIO enabled devices will initiate a magnet rate followed by a threshold test**	None

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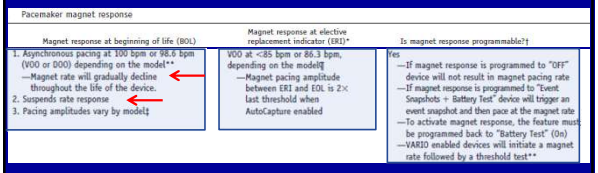
St Jude Medical



Pacemaker magnet response

Magnet response at beginning of life (BOL)	Magnet response at elective replacement indicator (ERI)*	Is magnet response programmable?†
1. Asynchronous pacing at 100 bpm or 98.6 bpm (VOO or DOO) depending on the model** —Magnet rate will gradually decline throughout the life of the device. 2. Suspends rate response 3. Pacing amplitudes vary by model‡	VOO at <85 bpm or 86.3 bpm, depending on the model‖ —Magnet pacing amplitude between ERI and EOL is 2× last threshold when AutoCapture enabled	Yes —If magnet response is programmed to "OFF" device will not result in magnet pacing rate —If magnet response is programmed to "Event Snapshots + Battery Test" device will trigger an event snapshot and then pace at the magnet rate —To activate magnet response, the feature must be programmed back to "Battery Test" (On) —VARIO enabled devices will initiate a magnet rate followed by a threshold test**

Should say Asynchronous Pacing at 100/98.6 (DOO, VOO, or AOO)

The newer models have a Bost Scient battery, thus 100 at BOL

HRS Guidelines somewhat confusing again

HRS Guidelines 2011

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Four Potential Magnet-Response Programming Options

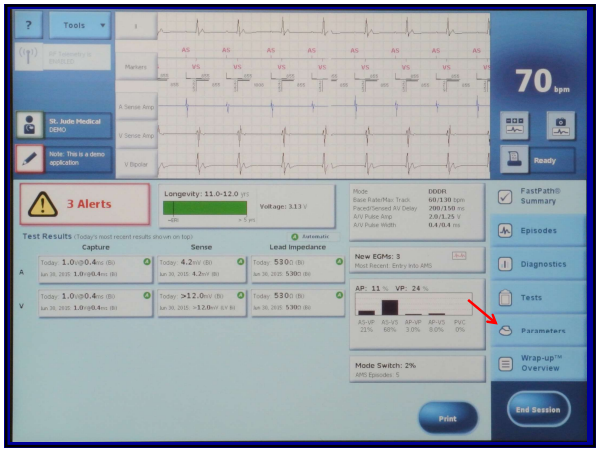
- Battery Test
- Battery Test + EGM
- Off
- Off + EGM

125

St Jude Magnet-Function Programmability

- Relatively easy to find the "Response" location

127



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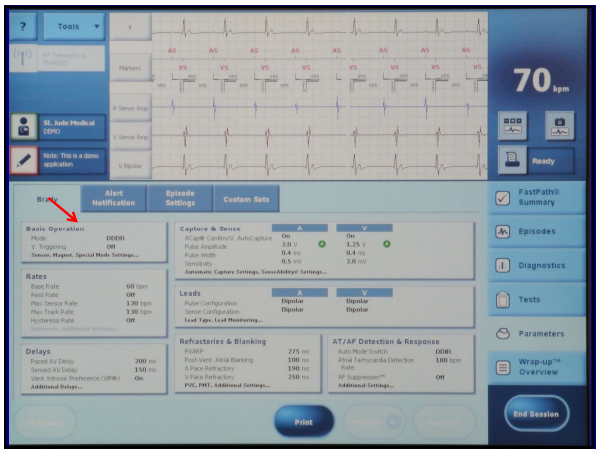
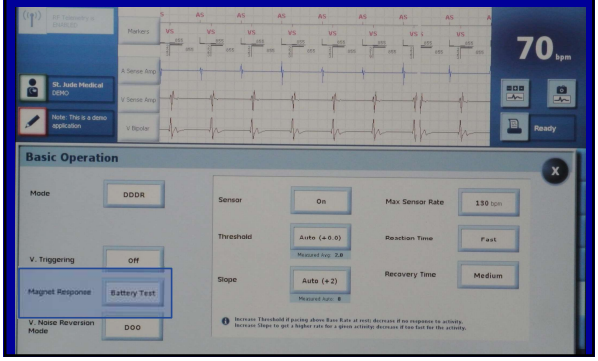


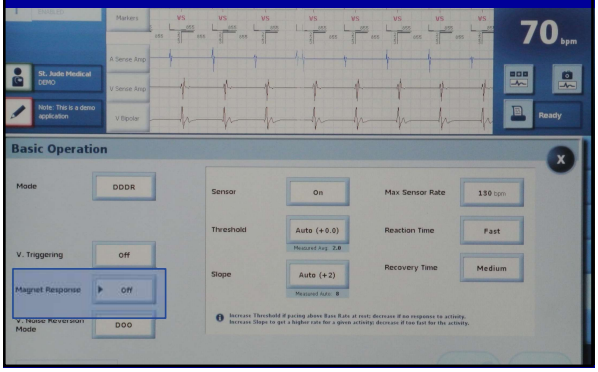
129

Option 1: Battery Test



130

Option 2: OFF



131

"Battery Test" Response

- Asynchronous pacing
  - DOO, VOO or AOO depending on base mode
  - A-V delay of 120 msec
  - Rate depends on remaining battery life and on model

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St Jude Pacer Magnet Pacing Rate

	BOL	ERI
Group 1 (older pacers)	98.6	86.3
Group 2 (newer pacers)	100	85

Group 1	Group 2
Affinity	Accent
Integrity	Anthem
ADx	Assurity
Victory	Endurity
Zephyr	Allure

133

"Off" Response

- Placement of the magnet over the pacer will not affect the pacing mode or rate
- RRM will not be turned off

134

St Jude Medical Programmability

Yes
- —If magnet response is programmed to "OFF" device will not result in magnet pacing rate
- —If magnet response is programmed to "Event Snapshots + Battery Test" device will trigger an event snapshot and then pace at the magnet rate
- —To activate magnet response, the feature must be programmed back to "Battery Test" (On)
- —VARIO enabled devices will initiate a magnet rate followed by a threshold test**

HRS Guidelines 2011

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What does this mean?

- There are two locations where the response to a magnet is controlled
  - Magnet Response section
  - Episode Triggers Section

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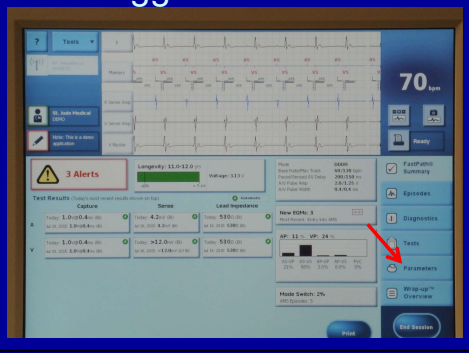
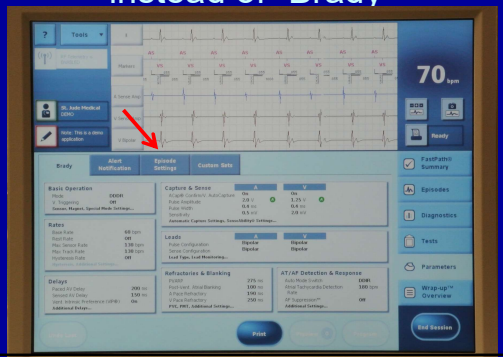
How does one find the Episode Triggers Section?



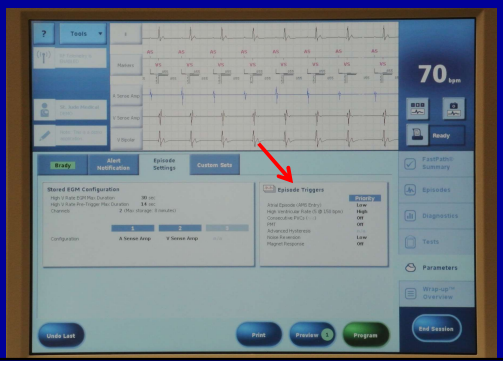
137

Choose "Episode Settings" instead of "Brady"



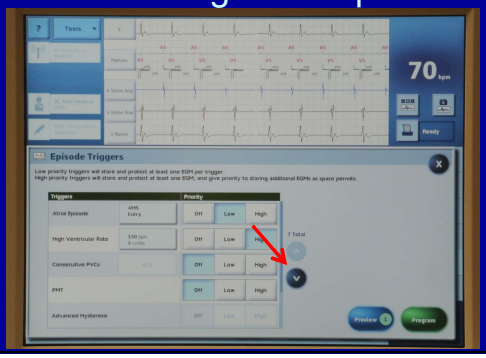
138

Choose "Episode Triggers"



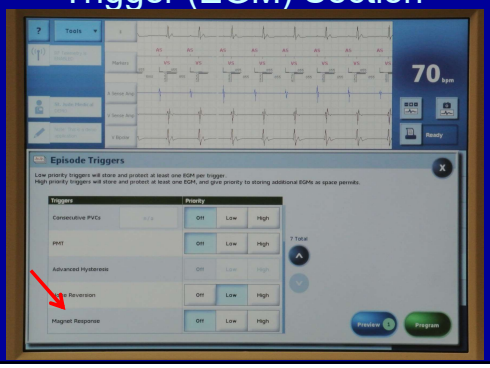
139

Episode Triggers—Scroll Down to find "Magnet Response"



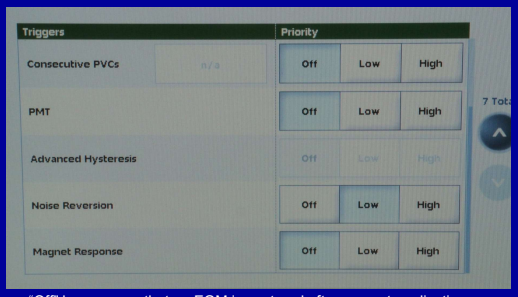
140

Magnet Response in Episode Trigger (EGM) Section



141

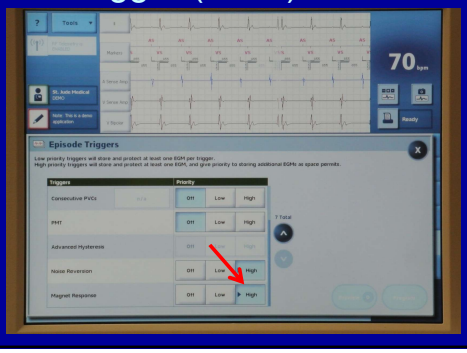
Magnet Response for Episode Trigger (EGM): OFF



"Off" here means that no EGM is captured after magnet application.
It does not have anything to do with Magnet Response in the "Brady" Tab

142

Magnet Response for Episode Trigger (EGM): ON



143

Episode Trigger (EGM) Response: Low or High

- When the magnet response in the Episode Trigger section is set to "Low or High", the magnet will cause the pacer to capture an EGM for approximately 2 seconds after the magnet is applied. After the EGM is captured, there is a 5 second delay, after which the magnet resumes whatever function that is set in the Pacing Magnet Response section—either "Battery Test" or "Off"

144

High vs Low

- The High or Low simply refers to the priority with which the EGMs are stored in the event that memory is short
- In both cases, a 2-sec EGM is stored

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Why does this Matter?

- If you place a magnet on a St Jude pacemaker and it does not appear to pace at 100 or 98.6 beats per minute, it may simply mean that for the first 7 seconds the magnet is in the process of capturing an EGM—when this process is complete the standard "battery test" magnet function will commence.

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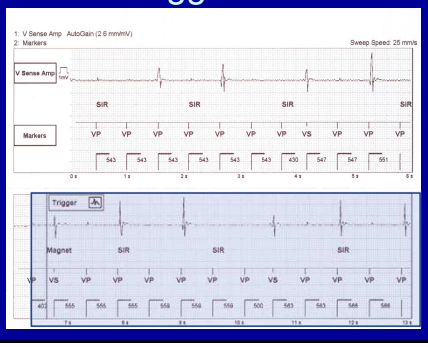
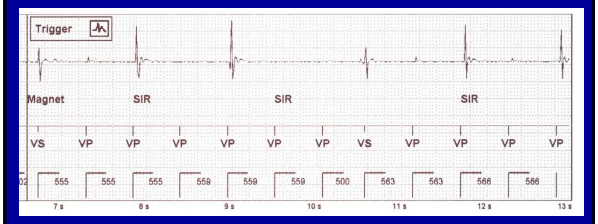
Magnet Response of St Jude Pacer in Trigger Low mode



147

Trigger Mode



Magnet pacing rate should be 98.6 or 100. What is the pacing rate?

60000/555=108 bpm

The SIR indicates Sensor Indicated Rate—rate response mode is active

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Trigger Mode continued

- After approximately 7 seconds the Magnet will inhibit the rate response mode and induce ASYNC pacing at 100.
- This delayed effect might lead one to believe that the magnet is not working, especially if the HR were 60.

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St Jude Magnet Response Summary

Magnet Response Parameter	Magnet EGM Trigger	Device Response
Off	Off	No response to magnet application
Battery Test	Low/High Priority (On)	EGM stored after a 2-second delay Asynchronous pacing at the magnet rate after a 5-second delay
Off	Low/High Priority (On)	EGM stored after a 2-second delay (No asynchronous pacing)
Battery Test	Off	Asynchronous pacing at the magnet rate (No EGM stored)

Battery Test + Trigger Off most common setting

Courtesy of St Jude Medical

150

St Jude Magnet Summary

- Typical magnet response=Asynchronous pacing at 98.6 or 100 bpm (DOO,VOO, AOO)
- The magnet pacing rate decreases over time to a nadir of 86.3 or 85 at ERI
- Pacemaker can be programmed to ignore the magnet
- Pacemaker can also be programmed to capture an EGM prior to asynchronously pacing

151

Programmabilitly Summary

- Biotronik, Bost Scientific, and St Jude pacers have specific magnet-response programmability
- Some Medtronic pacers have a post programming session issue that you must be aware of
- ELA/Sorin does not have any programmability

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Manufacturer	Magnet Response Programmability
Biotronik	Async Auto (almost Off) Sync (Off)
Boston Scientific	Async/Pace Async EGM/Store EGM (Off) Off
Medtronic	Post programming Issue Older devices may not respond for 60 min
Sorin	No programmability
St Jude	Battery Test Battery Test + EGM Off Off + EGM

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Magnet Super Summary

Manufact.	Mode	Tone	RRM	BOL	ERI	Change	Program.
Medtronic	D/V/AOO	No	Off	85	65	Binary	Yes
Biotronik	D/V/AOO	No	Off	90	80	Binary	Yes
Sorin/ELA	D/V/AOO	No	Off	96	80	Gradual	No
St Jude**	D/V/AOO	No	Off	98.6/100	86.3/85	Gradual	Yes
Boston Sci	D/V/AOO	No	Off	100	85	Gradual	Yes

Biotronik: Asynch--90 bpm continuously, Auto—90 for 10 beats only, Sync—no change
St Jude: Battery Test, Battery Test + EGM, OFF, OFF + EGM
Bost Scien: Pace ASYNC, EGM, OFF
Medtronic Pacers that will not respond to magnet for 60 minutes with standard end session: Kappa, EnPulse, Adapta, Versa, Sensia
St Jude Microny, Regency, Accent, Nuance, Anthem, Assurity, Endurity: 100/85

155

Key Message

- Always test the magnet function to confirm its effect on the pacer before a case begins

156

The End of Part 2

- This is where we will end the second of three sessions on Magnets
- The next lecture will review the safety aspects associated with the use of a magnet and a comprehensive review of what has been covered in the three sessions

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This material is for the use of members of the MGH DACCPM only

Perioperative Electrophysiology:

Perioperative Management of Pacemakers
Lecture #6
Magnets Part 3

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Massachusetts General Hospital
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I have no conflict of Interest

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What do you need to know about Magnets?

- Why you should use a Magnet?
- How will each type of pacer respond to a magnet in a typical situation
- How to use a programmer to understand the programmability associated with many of the pacemakers
- What are the risks associated with a magnet?

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Risks Associated with Magnet Use

- Patient discomfort
- Pacing at a high rate for too long could cause myocardial ischemia or hypotension
- R on T Phenomenon--VF

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R on T Phenomenon

- An asynchronous depolarization delivered in the descending limb of the T-wave may find conditions favorable to induce ventricular fibrillation

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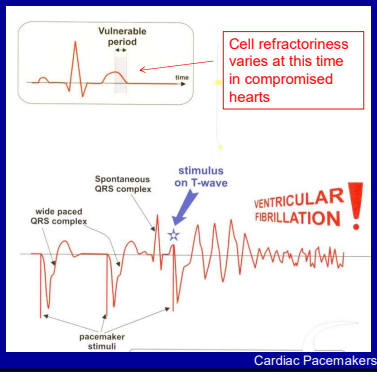
R on T can induce VF



Cardiac Pacemakers, SS Barold et al

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R-on-T Phenomenon

- Fibrillation is often initiated when a premature impulse arrives during the vulnerable period. In the ventricles this period coincides with the DOWNSLOPE of the T wave. During this period, the excitability of the cardiac cells varies. Some fibers are still in their effective refractory period, others have almost fully recovered their excitability, and still others are able to conduct impulses, but only at very slow conduction velocities. As a consequence, the action potentials are propagated over the chambers in multiple wavelets that travel along circuitous paths and at various conduction velocities. As a region of cardiac cells becomes excitable again, it will ultimately be reentered by one of the wave fronts traveling about the chamber. The process is self-sustaining.

Cardiac Physiology, Berne and Levy 7th ed, p.48-49

164

R on T Phenomenon

- People use magnets all the time
- Why do we need to worry?

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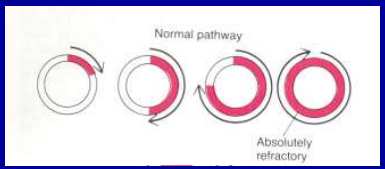
Normal Cardiac Conduction

- The AP travels through the entirety of the ventricular muscle mass, then the impulse dies because the entire heart is refractory—the cardiac impulse hits a dead end

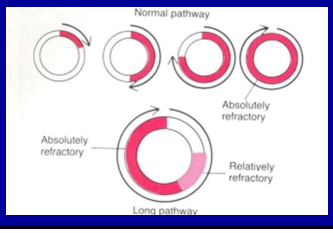


Guyton Textbook of Medical Physiology 9th ed p.154

167

Abnormal Cardiac Conduction

- Prolonged Pathways
- Decreased conduction velocity
- Reduced refractory periods



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Abnormal Cardiac Conduction

- Anything the creates the milieu for these three causes of abnormal myocardial conduction can then set up a situation where an ill-timed pacing impulse could precipitate VF

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What Causes these Abnormal Conditions in the OR?

- Elongation of the pathways in the heart
  - Dilated cardiomyopathy
  - Acute CHF
- Decreased conduction velocity
  - Ischemia
  - Hyperkalemia
  - Acidosis
  - Hypothermia
- Decreased Refractory Periods
  - Epinephrine
  - Sympathetic activation
  - Repetitive stimulation

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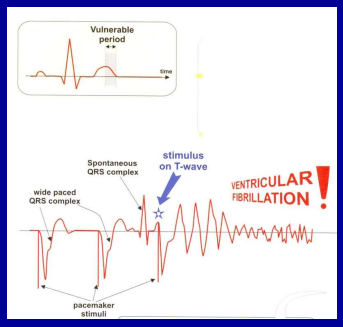
We Will See this in the OR if we are not Careful



Cardiac Pacemakers, SS Barold et al

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Pacer induced VF is RARE,

- But it is much more likely in patients with
  - Enlarged ventricles
  - Significant electrolyte abnormalities
  - Myocardial ischemia or infarction
  - Severe metabolic acidosis
  - Competing underlying rhythm

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So, Use a Magnet with Caution!

- Patient must be monitored
- If intrinsic rate > 85 be more careful
- If patient's heart is dilated or ischemic, or the patient has a metabolic misfortune, be more careful
- If you ever place a magnet on a patient's pacemaker, you should consider yourself that patient's ICD!

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Pacemaker Dependence Can Change during surgery

- If you place a magnet on a patient with a slow underlying rhythm, always look for evidence of a competing rhythm that might occur if surgical stimulation increases the intrinsic heart rate enough to compete with the magnet rate

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Use Magnet with Caution, Again

- If you ever place a magnet on a patient's pacemaker, you should consider yourself that patient's ICD!

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Use Asynchronous Pacing Modes with Caution

- If you reprogram a pacer to an asynchronous mode (especially DOO or VOO), consider yourself that patient's defibrillator until the pacer is back in a demand mode

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Lecture Summary 1/3

- Magnets have many uses
- Magnets placed over a responsive pacemaker activate a reed switch which alters the mode and rate of the pacer
- Pacemakers from each Manufacturer respond slightly differently to a magnet depending on the programming and remaining battery life

181

Lecture Summary 2/3

- Pacemakers from Bost Scientific, St Jude, and Biotronik can be programmed to ignore a magnet
- Some Medtronic Pacemakers will not respond to a magnet for 60 minutes after a programming session
- Always test the magnet before the procedure to make sure it does what you want it to do

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Lecture Summary 3/3

- The use of asynchronous pacing may precipitate VF if a pacing spike falls in the descending limb of the T-wave of a compromised heart
- Whenever you place a magnet on a pacer, or program a pacer to an asynchronous mode, you become that patient's defibrillator

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